



Changes in invertebrate taxa at two pre-Columbian sites in southwestern Jamaica, AD 800–1500

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Abstract

Excavations at two pre-Columbian sites at Paradise Park, Parish of Westmoreland, Jamaica, revealed significant changes in mollusk use through time. The sites are located on a low dune ridge in a tropical forest between a mangrove swamp and sawgrass morass on Bluefields Bay. One site (Wes-15a) dates to the 9th century AD and contains only Ostionan (redware) pottery. It is located 240 m to the east of a Meillacan (White Marl/Montego Bay style) site dated to the 15th century AD (Wes-15b). The molluscan fauna in the Ostionan site is dominated by species that prefer freely circulating, high salinity seagrass habitats (i.e., Strombidae, Cardiidae, and Veneridae). In marked contrast, Lucinidae and Melongenidae dominate the Meillacan deposits, taxa that favor habitats of low circulation, lower salinity, and muddier substrates that are often associated with mangroves in Jamaica. Cultural and environmental factors that may have contributed to the observed shift in resource use are discussed.

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Human impacts on terrestrial animal species have been the subject of collaborations between archaeologists and ecologists for years [18,24,30]. Yet such collaborations have only recently begun with regard to coastal habitats. The goal of this paper is not to review those studies, nor to justify their importance [14]. Our present objectives are far more limited. Research in southwestern Jamaica revealed adjacent archaeological deposits composed of markedly different marine mollusk shells. This situation provides an excellent opportunity to investigate human–environmental interactions at two distinct time periods. The major goal of this paper is to draw attention to human impacts on coastal habitats in the recent past, and to illustrate the speed with which such changes can take place. We begin with a review of the study area and sampling strategies, then describe the invertebrate assemblages, and finally consider the cultural and natural processes that may have generated the observed patterns.

1. Study area

Between 1998 and 2002, Keegan spent 17 weeks directing excavations at two pre-Columbian sites at Paradise Park, a tropical dairy in southwestern Jamaica near the town of Savanna-la-Mar (Fig. 1). The property is on a low-lying coastal plain with the deeply weathered Chebucktoo karst hills to the east. The seaward margin is a series of arcuate, sub-parallel former beach ridges aligned to the present shore [1]. The coastal zone presently is prograding as indicated by mapping undertaken in 1971 and again in 1991 (Fig. 2). There is a fringe of red mangroves along the coast. The soils are alluvial and mangrove swamp loams and clays with medium to coarse, moderately sorted carbonate sand of marine origin. Burrowing land crabs (*Gecarcinus* sp.) are active in the area; in fact, the sites were found because crabs had moved artifacts to the ground surface.

The two sites are situated on the second fossil dune from the coast. There are freshwater swamps, which exhibit tidal effects, to the north and south, and the dune is only 1 to 1.5 m above MSL. The vegetation is natural

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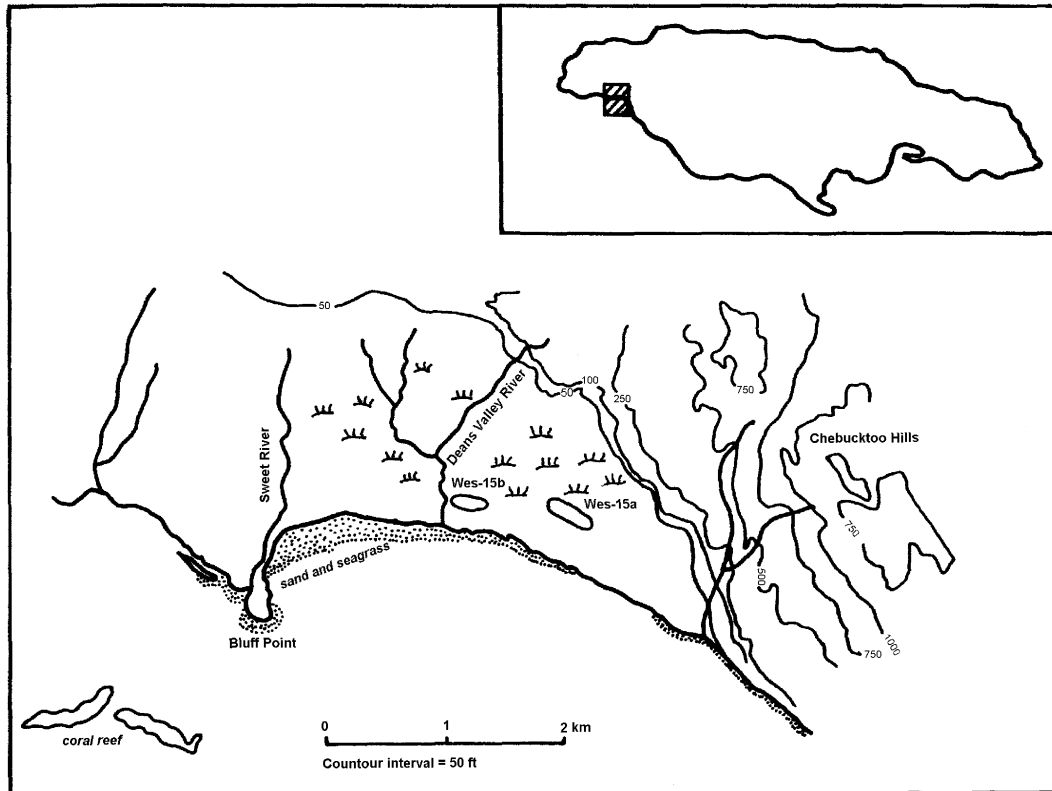


Fig. 1. Overview map of the study area. The archaeological sites are the ovals at the center of the map (Wes-15b and Wes-15a).

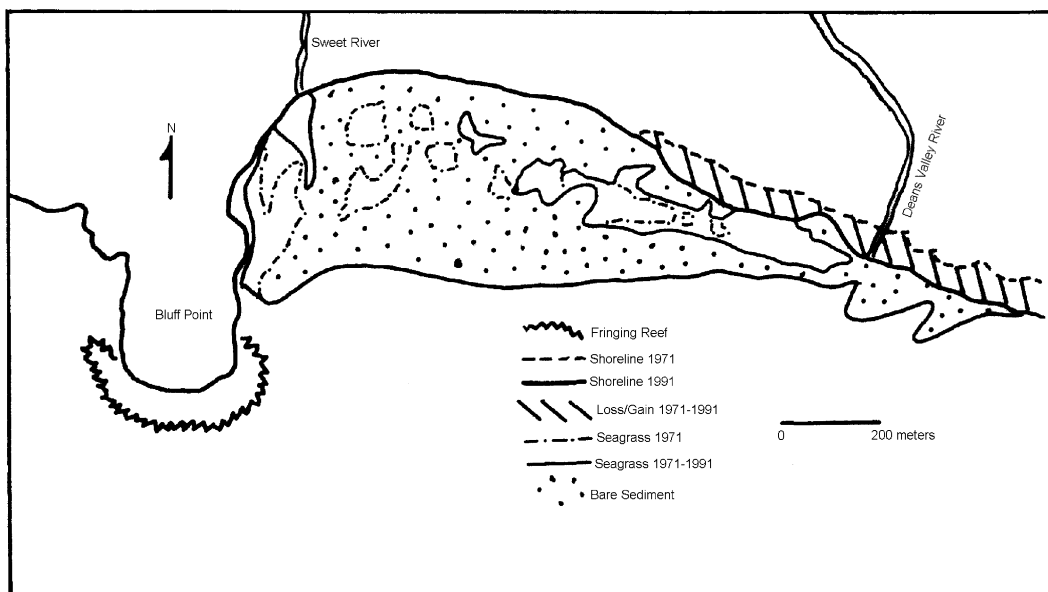


Fig. 2. Distribution of seagrasses, bare sand and coral reefs in Bluefields Bay. The map illustrates changes in their distribution between 1971 and 1991. The archaeological sites are on the eastern side [1].

sea level coastal tropical forest, and is dominated by large trees. The Ostionan site is dominated by Royal Palm (*Roystonea princeps*), while the other site has mostly hardwoods.

One assumption of this study is that the terrestrial environment of the sites did not change significantly, or at least not to the degree that would have influenced the use of the marine environment. The analysis of

sediments in the sites is planned and should help to address this assumption. In the meantime, there are indicators of environmental stability. For many years the site was used as an unpaved road connecting Cave Settlement and Savanna-la-Mar. Although this use compacted the deposits, it also prevented significant subsurface disturbances. Second, there is a Ceiba tree (*Ceiba pentandra*) growing on the Meillacan site that is about 25 m tall. Bill Rogers (a forester from Tallahassee, FL) observed the tree and estimated that it was 200–300 years old.

Finally, because the subject of this paper is invertebrates, we should note that land snails on the site suggest very little change in the humid tropical character of the entire dune. The two most common taxa are *Pleurodonte chemnitziana* and *P. pallescens*, which live predominantly in wet forests. They are very common on tree trunks and in leaf litter, and masses of shells from dead animals litter the ground. They are also very common in both sites, with no significant difference in their numbers. The jury is still out on whether or not they were eaten in the past, although they offer 4 g of easily obtained meat. The important point is that they represent a constant in the environment from the 9th century to the present.

The Meillacan site (Wes-15b) is located 900 m to the east of the Dean's Valley River. The site measures 220 m east/west.¹ There currently is only one radiocarbon date for the site made on charcoal collected from a deep cultural deposit: cal AD 1430 (2 σ 1320–1490; Beta-125833). In addition, faunal analysis revealed European introductions to significant depths (e.g., *Rattus rattus* to 70 cmbs). Clearly, the site was occupied into historic times [5]. A total of 82 m² have been excavated, primarily in two large block excavations of 41 and 35 m². The deposit ranges in depth from 20 cm to 1 m.²

The Ostionan site is 240 m beyond the eastern boundary of the Meillacan site, and extends for 400 m.

¹ The east/west dimensions are based on 50 cm² test units that were dug at 20 m intervals from the river to the end of the dune, a distance of about 3 km. North/south dimensions are more variable and essentially correspond to the margins of the dune, which ranges from 60 to 100 m wide.

² *Sampling strategy*: both sites were excavated in the same way with pointing trowels and finer tools. When differences in strata were not obvious the units were excavated in 10 cm levels. Whenever possible, levels were based on strata, which was made easier by excavating in contiguous units. All soil was sieved through 5 mm mesh hardware cloth, and four to eight liter bulk samples were collected from most levels and wet sieved on 2 mm mesh screens. It was in the fine-screen that most of the echinoid parts were recovered. Shells were washed, sorted, identified, and mostly discarded at the field laboratory in Jamaica. All of the mollusk identifications were made by Keegan, based on 20 years of experience in archaeological shell analysis. Uncommon species were tentatively identified using field guides, and field IDs were brought back to Gainesville for identification. Echinoids were identified by Portell using the collections of the Florida Museum of Natural History.

The one radiocarbon date, made on conch shell from the lowest cultural horizon, is cal AD 850 (2 σ 710–990; Beta-125832). The date is consistent with other Jamaican sites, where the pottery style is dated to circa AD 650–950. A total of 29 m² were excavated in two block excavations called “Areas”. Area 300 is on the backslope of the southern side of the dune; Area 400 is 100 m to the east and about 20 m higher up on the dune (north).

The Ostionan and Meillacan sites have completely different pottery assemblages (Little River versus White Marl/Montego Bay styles, respectively) with no overlap. Their vertebrate and invertebrate remains also are substantially different. The present study focuses on the use of invertebrates and the information these provide concerning changes in cultural behavior and environmental parameters. In sum, the invertebrate remains represent two distinct uses of the same geographical space from a relatively constant terrestrial habitat.

2. Marine invertebrate ecology and human predation

In terms of diversity, 64 marine mollusks, 3 echinoids, and 8 corals were identified (Table 1). The data in Table 1 are presented as presence/absence, rather than numerical values, to illustrate the substantial number of species identified and the high degree of overlap. The Ostionan and Meillacan sites have 48 molluscan taxa in common, and those that they do not share were uncommon in the deposits. Because most of the same species were present during both time periods, the question is whether the change in abundance is due to changes in the way humans used mollusks or whether these differences reflect changes in their relative availability in the marine environment. Because environmental preferences reported in the literature are valid at the level of family; genus and species data have been aggregated. The comparisons that follow are made at the taxonomic level of family (Tables 2 and 3). Our focus is the six most common families of marine mollusks. Echinoids and corals also are mentioned because they too can provide information about changing environments and changing resource use.

With regard to sample size, the Ostionan site had 3881 NISP (MNI=856) and the Meillacan site had 10,637 NISP (MNI=4466) of the six most common families in the sample.³ Because the tables were built up by successively adding excavation areas, we observed substantial changes in the relative frequencies as new units were added. If you compare Tables 2 and 3, you observe that the relative percentage of MNI for each family is very similar to the relative percentage of NISP. At small sample sizes the relative percentages of MNI

³ NISP is number of identified specimens; MNI is minimum number of individuals.

Table 1

Presence (×) and absence (–) of invertebrates at Wes-15a and Wes-15b (taxonomic names follow conventions in: [21,22,28])

	Wes-15a	Wes-15b
Mollusks (marine)		
<i>Americardia media</i>	×	×
<i>Anadara notabilis</i>	×	×
<i>Anodontia alba</i>	×	×
<i>Anomalocardia brasiliana</i>	×	×
<i>Arca zebra</i>	×	×
<i>Asaphis deflorata</i>	×	×
<i>Astrarium phoebium</i>	×	–
<i>Atrina rigida</i>	–	×
<i>Brachidontes</i> spp.	×	×
<i>Bulla striata</i>	×	×
<i>Cassis madagascarensis</i>	×	×
<i>Chama</i> sp.	×	×
<i>Charonia variegata</i>	–	×
<i>Chicoreus brevifrons</i>	×	×
<i>Chione cancellata</i>	×	×
chitons	×	×
<i>Cittarium pica</i>	×	×
<i>Codakia orbicularis</i>	×	×
<i>Cryptostrea permollis</i>	–	×
<i>Cymatium femorale</i>	×	×
<i>Cyphoma gibbosum</i>	×	×
<i>Cypraeacassis testiculus</i>	×	×
<i>Dendrostrea frons</i>	×	×
<i>Diplodonta punctata</i>	×	×
<i>Divalinga quadrisulcata</i>	×	×
<i>Donax</i> spp.	×	×
<i>Fasciolaria tulipa</i>	×	×
<i>Glycymeris pectinata</i>	×	×
<i>Isognomon alatus</i>	×	×
<i>Laevicardium laevigatum</i>	×	×
<i>Lirophora paphia</i>	×	–
<i>Lithopoma caelatum</i>	×	×
<i>Lucina pectinata</i>	×	×
<i>L. pensylvanica</i>	–	×
<i>Macrocypraea zebra</i>	×	–
<i>Melongena melongena</i>	×	×
<i>Modiolus americanus</i>	×	×
<i>Natica</i> spp.	×	×
<i>Nerita</i> spp.	×	×
<i>Neritina</i> spp.	×	×
<i>Oliva</i> spp.	×	×
Patellogastropoda	–	×
Pectinidae	×	–
<i>Periglypta listeri</i>	×	×
<i>Pitar albida</i>	–	×
<i>P. dione</i>	–	×
<i>Plicatula gibbosa</i>	×	×
<i>Prunum guttatum</i>	×	×
<i>Puberella interpupurea</i>	×	×
<i>Solecurtus cumingianus</i>	×	–
<i>Strombus alatus</i>	×	×
<i>S. costatus</i>	×	×
<i>S. gigas</i>	×	×
<i>S. pugilis</i>	×	×
<i>S. raninus</i>	×	×
<i>Tectarius muricatus</i>	×	×
<i>Tellina fausta</i>	×	×
<i>T. magna</i>	×	×
<i>T. radiata</i>	–	×
<i>Tivela mactroides</i>	×	×

Table 1 (continued)

	Wes-15a	Wes-15b
<i>Trachycardium muricatum</i>	×	×
Turbininae	×	–
Mollusks (terrestrial)		
<i>Pleurodonte chemnitziana</i>	×	×
<i>P. pallescens</i>	×	×
Echinoids		
<i>Clypeaster rosaceus</i>	×	×
<i>Eucidaris tribuloides</i>	×	–
<i>Meoma ventricosa</i>	×	–
Corals		
<i>Acropora cervicornis</i>	×	×
<i>A. palmata</i>	×	×
<i>Diploria</i> spp.	×	×
<i>Manicina areolata</i>	×	×
<i>Millepora</i> spp.	–	×
<i>Montastrea</i> spp.	×	×
<i>Porites porites</i>	×	×
UID encrusting coral	–	×

and NISP were often very different. It was only after our sample reached about 3000 NISP and 800 MNI that the relative percentages of both reached stable ratios. In other words, very small sample sizes probably do not accurately reflect invertebrate use at archaeological sites.

2.1. Marine gastropods

Access to a rocky intertidal habitat is limited to the shore along Bluff Point (Fig. 2). Not surprisingly, species from this habitat are not common in the site deposits. However, one important species, *Cittarium pica*, merits comment [19]. The West Indian Top Shell was collected and eaten throughout the West Indies whenever it was available [4]. It was also an important tool source at various sites [15]. *Cittarium pica* is more common in the Ostionan midden (MNI=20), with only three MNI recovered from the Meillacan midden despite a substantially larger sample size. Its presence in the Ostionan deposit likely reflects its availability on the rocky shoreline near Bluff Point where it could easily have been collected during fishing expeditions to the nearby coral reef. The virtual absence of *C. pica* from the Meillacan midden may reflect its local extirpation at the hands of Ostionan foragers.

The main marine gastropods in the Ostionan site are Strombidae. Strombids are common on well-developed *Thalassia* seagrass communities. Their ecology has been widely discussed in the literature and will not be reviewed here. The decline in strombids between the two sites is dramatic, with almost four times as many specimens represented in the Ostionan site (32% [MNI=32])

Table 2
MNI of major mollusk families in the two sites

	Wes-15a		Wes-15b	
	MNI	%MNI	MNI	%MNI
Strombidae	272	32	349	8
<i>Strombus gigas</i>	32		40	
<i>S. raninus</i>	90		174	
<i>S. pugilis</i>	125		93	
<i>S. costatus</i>	6		10	
<i>S. alatus</i>	7		14	
Small <i>Strombus</i> sp.	12		18	
Melongenidae	36	4	379	8
<i>Melongena melongena</i>	36		379	
Lucinidae	34.5	4	2133.5	48
<i>Lucina pectinata</i>	5		1740	
<i>Codakia orbicularis</i>	26.5		376	
<i>Anodontia alba</i>	3		17.5	
Veneridae	137.5	16	614.5	14
<i>Chione cancellata</i>	35.5		120	
<i>Puberella interpurpurea</i>	17		32.5	
<i>Lirophora paphia</i>	0.5		1.5	
<i>Periglypta listeri</i>	8.5		13	
<i>Pitar albida</i>	3.5		3.5	
<i>Tivela mactroides</i>	64.5		287	
<i>P. dione</i>	1.5		3	
<i>Anomalocardia brasiliana</i>	6.5		154	
Cardiidae	75	9	94	2
<i>Laevicardium laevigatum</i>	43.5		17	
<i>Americardia media</i>	20		27.5	
<i>Trachycardium muricatum</i>	11.5		49.5	
Arcidae	301	35	896	20
<i>Arca zebra</i>	166.5		238	
<i>Anadara notabilis</i>	134.5		658	
Totals	856	100	4466	100

Table 3
NISP of major mollusk families in the two sites

	Wes-15a		Wes-15b	
	NISP	%NISP	NISP	%NISP
Strombidae	2150	55	1148	11
<i>Strombus gigas</i>	1709		590	
<i>S. raninus</i>	115		235	
<i>S. pugilis</i>	197		130	
<i>S. costatus</i>	15		19	
<i>S. alatus</i>	9		16	
Small <i>Strombus</i> sp.	105		158	
Melongenidae	69	2	895	8
<i>Melongena melongena</i>	69		895	
Lucinidae	211	5	5071	48
<i>Lucina pectinata</i>	25		3982	
<i>Codakia orbicularis</i>	180		1045	
<i>Anodontia alba</i>	6		44	
Veneridae	536	14	1285	12
<i>Chione cancellata</i>	90		242	
<i>Puberella interpurpurea</i>	45		68	
<i>Lirophora paphia</i>	1		2	
<i>Periglypta listeri</i>	77		71	
<i>Pitar aresta</i>	7		6	
<i>Tivela mactroides</i>	299		582	
<i>P. dione</i>	3		6	
<i>Anomalocardia brasiliana</i>	14		308	
Cardiidae	282	7	373	4
<i>Laevicardium laevigatum</i>	125		93	
<i>Americardia media</i>	55		70	
<i>Trachycardium muricatum</i>	102		210	
Arcidae	633	16	1865	18
<i>Arca zebra</i>	319		522	
<i>Anadara notabilis</i>	314		1343	
Totals	3881	99	10637	101

vs. 8% [MNI=349] of MNI; see Tables 2 and 3). What factors might have contributed to this shift in relative percentage?

First, it should be recognized that among the available mollusks the Strombidae provide the largest packages of meat. They are highly visible epifaunal feeders, are easily collected and processed, and seem to have been exploited, and over-exploited, whenever available. From the first inhabitants of the West Indies to the present, strombids have been a valued resource [27]. It is therefore expected that they were collected whenever they were encountered. The relative absence of strombids in the Meillacan site suggests that they were no longer common in the bay.

It is possible that few strombid shells were found in the Meillacan site simply because the shells were not brought to the site. There was no reason to transport the heavy adult shells to a site unless they were intended for

use in tool making [15]. For this reason the consumption of conch probably has been underestimated. Large piles of mostly adult conch along the coasts of many islands attest to the practice of removing the meat and discarding the shell on the beach. That larger shells were more common, but were broken to make tools, is apparent in the ratios of NISP to MNI at the two sites. At the Ostionan site there were 1709 NISP of *Strombus gigas* but only 32 MNI, while at the Meillacan site the ratio was 590 NISP to 40 MNI. The reason that the MNI/NISP ratio is greater in the Meillacan site is because there were more complete small, sub-adult *S. gigas* in the deposit.

The practice of discarding shells on the beach may characterize the discard of adult *S. gigas* shells, but it does not hold true for small *Strombus* spp. shells (<14 cm). Small strombids seem always to have been brought to the sites for food processing. The meat was

removed and the shells were discarded in the village middens. This pattern of discard is common throughout the northern West Indies [6]. The substantial number of small strombids in the Ostionan site also attests to this practice. If small strombids were available, then we would expect a similar pattern of discard in the Meillacan site as well.

We interpret their relative absence from the Meillacan site as a direct reflection of their distribution in the environment. In other words, strombids were not common in Bluefields Bay during Meillacan times. It is possible that their exploitation during Ostionan times led to their local extirpation [27]. In this regard, the availability of nursery grounds to provide a source of young conchs needs to be considered. Stoner has shown that the availability of *S. gigas* is highly dependent on marine circulation and adequate nursery grounds on which the young conchs develop [25,26]. The absence of substantial numbers of juvenile *S. gigas* (1 and 2 year age classes) in the Ostionan site suggests that Bluefields Bay was never a good nursery ground. Moreover, changes in the bay's marine environment, discussed below, may have acted in concert with human predation to limit their availability by Meillacan times.

The relatively high frequency of the crown conch, *Melongena melongena*, in the Meillacan deposit (8% [MNI=379] vs. 4% [MNI=36] of NISP) supports this conclusion (Tables 2 and 3). Crown conch are similar in size to small Strombidae so we would expect the shells of the latter to be present as well if they were being captured. The opposite should also be true; if crown conch were abundant during Ostionan times then they should have been collected. *Melongena melongena* is found on *Thalassia* beds in 0.3 to 10 m of water, is abundant in mangrove areas, and is most common in sheltered, muddy areas along the south coast of Jamaica [11].

The difference between Strombidae and Melongenidae with regard to environmental parameters is that the former prefers and is more abundant on seagrass beds, while the latter favors and is more abundant in mangroves and mud flats. Because people targeted both species their relative abundance in the sites should mirror their availability in the environment. The shift from seagrass to mangrove foraging strongly suggests that changes in the coastal environment also took place.

2.2. Marine bivalves

Before making specific comparisons we need to note that several taxa that are common in the Ostionan site have been excluded from this study. Although *Chama* spp., *Dendrostrea frons*, and *Arca zebra* are far more common in the Ostionan deposit, they were most common in the deepest levels in contexts that are not clearly cultural. Moreover, in the deepest levels they often occur

as articulated valves and aggregates.⁴ In addition, all of the *D. frons* were recovered from Area 300; an area that the echinoid data suggests is a natural context (see below). These taxa likely reflect the natural deposits on which humans first settled and are unrelated to subsistence practices. Rather than introduce a potentially biased subset of the sample, we will focus on mollusks that more clearly reflect environmental conditions.

With regard to the infaunal mollusks, the major shift is from taxa that inhabit free-circulating marine systems of high salinity to those that are tolerant of more stagnant and lower salinity habitats that are often associated with mangroves. Jeremy Jackson, in his study of Discovery Bay on the north coast of Jamaica, notes that “physiological tolerance may be of major importance in determining differences in frequency of dominant bivalve species within *Thalassia* environments” [13].

For comparative purposes it is worth emphasizing the most common mollusk families in both sites (Tables 2 and 3). Several trends immediately are apparent. First, the most common bivalves in the Ostionan site are Cardiidae (e.g., *Trachycardium muricatum*, *Americardia media*, *Laevicardium laevigatum*) and Veneridae (e.g., *Periglypta listeri*, *Chione cancellata*). In contrast, the Meillacan site contains far more bivalves of the Lucinidae family (e.g., *Lucina pectinata* and *Codakia orbicularis*).

Cardiidae and Veneridae do not tolerate stagnant conditions. They are most common in predominantly coarse sand substrates with low silt content and continually well-circulating waters. They are shallow burrowers (1–3 cm), and are less tolerant of temperature fluctuations [23]. “*Thalassia* seagrass environments deeper than 1 to 2 m are dominated by these eulamelli-branch suspension-feeders [Cardiidae and Veneridae], although Lucinidae also are present” [13, p. 330]. Cardiidae and Veneridae have a relatively complex feeding apparatus and cannot accommodate large food particles in the way that Lucinidae can.

“Only Lucinidae...are present in any abundance on back-reef flats of *Thalassia*” [13]. They are deep burrowers (6–15 cm) and are tolerant of large temperature fluctuations and stagnant conditions [23]. For example, the Tiger Lucine, *C. orbicularis*, is tolerant of low salinity, and lives in anaerobic sediments where its food is synthesized by chemoautotrophic sulfur bacteria in its gills [2]. The most common Lucinidae in our sites, *L. pectinata*, is most often found in the vicinity of mangrove swamps in Jamaica [11].

⁴ *Arca zebra* is included in Table 2 and Table 3 for comparison to *Anadara notabilis*. Both are epifaunal bivalves that are found in very similar habitats. Yet *A. zebra* is more common in the Ostionan deposit while the latter is more common in the later deposit. Even if most of the *A. zebra* shells were part of the original soil matrix, why are they less common in the soil matrix of the later deposits? Food for thought.

Table 4
Average size and population density of *Codakia orbicularis* as a function of water depth [12]

Water depth	Shell length (cm)	Population density
4 m	0.99	Na
2 m	2.58	10.5/m ²
20 cm	3.11	58.3/m ²
10 cm	4.16	18.75/m ²

The mollusks in the site deposits reflect substantially different foraging strategies. Ostionan foragers collected shallow burrowing (1–2 cm) Cardiidae and Veneridae from sandier substrates in deeper water, possibly up to 2 m deep. Members of both families are easily collected. Evidence for their presence is visible on the substrate, or, as Humfrey [11, p. 245] notes, “a vigorous raking of the bottom quickly brings them [*T. muricatum*] to the surface.” In our opinion, they were not the primary target of foraging expeditions, but rather were collected incidental to fishing trips to the reef or while foraging for larger epifaunal mollusks such as *S. gigas* and *Cassia madagascarensis*. Although the environment that they occupy has a high species diversity, it offers a lower overall biomass.

In contrast, infaunal bivalves must have been a primary target of Meillacan foragers. The deep burrowing (10–15 cm) Lucinidae are most common in very shallow water. Jackson found the highest population density for *C. orbicularis* at a depth of 20 cm [12]. He also noted that the average shell length decreases with increasing water depth (Table 4). The average (mean) size of measured *C. orbicularis* valves from the Meillacan site is 4.92 cm ($\delta=1.07$, $n=75$). This average exceeds that recorded by Jackson, but serves to indicate that foraging was conducted in very shallow water. Infaunal bivalves in shallow-water environments are larger in size due to environmental stresses [12,13]. Thus, while species diversity is low, available biomass is relatively high. With regard to meat yields, Berg et al. report that 50–60 *C. orbicularis* clams were needed to yield about 200 g of wet meat [3].

The harvesting of Lucinidae required a focused effort. There is no clear evidence on the substrate of these deeply buried clams. Working in shallow water the collector probably knelt on the substrate and either dug with their hands at intervals or used a probe to identify buried clams before digging. In this strategy, the epifaunal *M. melongena* likely was captured incidental to the collection of bivalves. Meillacan peoples did not totally abandon foraging in deeper waters. *Tivela mactroides* and *Anomalocardia brasiliensis* are both found on sandy substrates in water between 1 and 2 m deep [11]. This habitat would also account for the high incidence of Arcidae, especially *Anadara notabilis*. However, these mollusks represent substantially less

biomass than do those from shallow water and mangrove habitats.

2.3. Echinoids

The majority of the echinoid fragments are from our 2000 excavations at the Ostionan site. In addition, one species of echinoid (*Clypeaster rosaceus*) has been identified from the Meillacan site, but this nearly complete specimen comes from the sand substrate below the cultural deposit and is a natural occurrence. The echinoid data document a new area of echinoid use in the West Indies, and provide information on associated marine environments.

A total of 16 test fragments were recovered. Seven fragments came from Area 300 and nine from Area 400. All of the fragments in Area 300 are from the irregular echinoid, *C. rosaceus*. They are distributed throughout the deposit between 15 and 60 cm below ground surface. The soils in this area have a much higher silt and clay content than do those in Area 400. Therefore, it is possible that Area 300 is a natural marine sediment deposit containing echinoid fragments in which cultural materials were redeposited.

In contrast, the Area 400 units have a sandy loam soil. Echinoid fragments from Area 400 are concentrated between 45 and 65 cm below ground surface, which corresponds to the primary occupation of the site. Moreover, we recovered all three of the echinoid taxa that were identified. Specimens from Area 400 likely reflect human activities, and provide additional evidence for reconstructing the local marine environment.

The majority of the test (endoskeleton) fragments examined (13 out of 16) come from the irregular echinoid, *C. rosaceus*. A second taxon, the regular echinoid, *Eucidaris tribuloides* also was identified. The two specimens examined were small, well-preserved, primary spines (radioles). Lastly, a single test fragment of ambulacra with pores came from *Meoma ventricosa*.

The presence of these taxa are evidence for a marine environment dominated by *Thalassia* grass and fringing bare sandy areas [21]. Because of their size and visibility all three taxa easily could have been collected, especially at night when they feed. *Clypeaster rosaceus* does not burrow, *M. ventricosa* does burrow but leaves a small telltale mound, and *E. tribuloides* is an epifaunal grazer. Whether these three echinoids were consumed for food is unknown, although the gonads of regular urchins have been eaten for several thousand years [8]. In addition, the larger, relatively stout radioles of *E. tribuloides* could be used as files for very fine woodworking.

2.4. Corals

Eight taxa of corals were recovered from the two sites (Table 1). As with all materials we need to consider the

role of humans in bringing them to the site. The nearest coral reef is near Bluff Point (Fig. 1), which is over 2 km from the sites by water. It is possible that corals were scavenged from the beach, but the location of the reef to the west of Bluff Point limits the transport of corals. As a result, corals are rare on the beach near Paradise Park. It also has been suggested that the polyps of corals scavenged from the beach typically are too abraded to be of use as tools, and that live corals collected on the reef were preferred. Corals from both sites show evidence of use as drills, rasps, and abraders, although a detailed analysis of use-wear has yet to be conducted.

With regard to the aboriginal environment, the presence of rose coral (*Manicina areolata*) at both sites is of special note. Rose coral lives unattached on the substrate in an environment of coral rubble, sand, and turtle grass. It is resistant to the effects of sediment, fluctuating temperature, and exposure during very low tides [22]. Although it prefers calm waters, it has a remarkable ability to right itself when overturned. It is a good indicator of a well-developed *Thalassia* seagrass habitat in Bluefields Bay during Ostionan times. It is somewhat less common in the Meillacan deposit, which may indicate a degradation of the seagrass environment by this time.

3. Changes in the marine environment

Human predation is only one side of the equation; predation is predicated on the availability of prey. In this regard we now address whether there were significant changes in the physical environment that contributed to changes in the abundance and availability of particular taxa. We begin with the decline in *S. gigas* over time, and then examine the habitats of the bivalves.

The location of Bluefields Bay on the southwest side of the island shelters it from prevailing meteorological and oceanographic conditions [1]. This location may limit the transport of planktonic *S. gigas* veligers into the bay, thus limiting the ability of the *S. gigas* population to recover from intense predation. The low frequency of juvenile *S. gigas* in both sites supports the conclusion that the bay was not a significant nursery area. *Strombus gigas* may have continued to thrive in deeper water outside the range of Amerindian fishing technology, but for all intents and purposes the local population had been extirpated. Thus, the characteristics of the physical environment contributed to the decline in the near-shore population by limiting the recruitment rate.

During the Ostionan occupation the invertebrate remains are indicative of a free-circulating marine environment with higher salinity and a well-developed *Thalassia* seagrass community. By Meillacan times the bay apparently had less marine circulation, lower salinity, a muddier substrate, a degraded seagrass

habitat, and perhaps a more developed mangrove habitat. Today the adjacent shoreline is very shallow with a 1–2° seaward gradient for 1–2 km before reaching the island slope and coral reef. The sediments are carbonate, algal, molluscan, and echinoid, which is typical of seagrass environments, and may account for some of the echinoid fragments in the Ostionan site (especially in Area 300). There is also carbonate mud, which supports anaerobic bacteria, and the sediments have a sulphurous smell in some areas, substrates that favor Lucinidae. Seagrasses and bare sediments dominate the substrate (Fig. 2). The most common species are turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*), but there are also fleshy and calcareous macro-algae, including *Dictyota* sp., *Ulva* sp., and *Halimeda* spp. The seagrass beds are not well developed, and there has been a recent disappearance of seagrasses in the bay that is probably due to excessive nutrient loads and water column anoxia associated with hypereutrophication [17].

The relative abundance of different species of mollusks, other than *S. gigas*, was closely tied to the availability of suitable habitats. We propose that between the 9th and 15th centuries that access to seagrass habitats declined, while mangrove habitats increased. Two factors affecting the marine environment were changes in eustatic sea level and changes in rainfall patterns. Although other factors likely played a role as well, it is these two in concert that were most important.

First, research in Florida and the Turks and Caicos Islands has shown that sea level was perhaps a meter lower when the Ostionan site was first occupied [20,29].⁵ This would help to explain why part of the Ostionan deposit is today below the water table. Furthermore, Bluefields Bay is extremely shallow; a meter drop in sea level would have had a significant impact on near-shore marine habitats. The area of seagrass habitat also would be much reduced. It is clear that there was a well-developed seagrass habitat, but it may have been at the greater depths (>1–2 m) that favor Cardiidae and Veneridae. These habitats would also be closer to the reef, which could explain the greater diversity of corals and larger fishes in the site. As sea level rose, shallower, higher-stress seagrass habitats, which favor Lucinidae, would have formed. A coastal mangrove swamp also could have developed.

⁵ The effects of eustatic sea level changes will be mediated by the geological activity of an island (i.e., relative sea level). Thus, the effects on Grand Turk (Bahama Platform) may not be the same as those on Jamaica (Caribbean Plate). In the present case these differences do not appear to be significant. The Paradise Park sites are only 1–1.5 m above MSL. Because Jamaica is actively emerging on the Caribbean Plate it is hard to justify any significant rise without putting the sites underwater (the deeper deposits in the Ostionan site are already underwater). Additional research is needed to investigate the hypothesized impacts of the proposed fluctuations in sea level.

Second, paleoenvironmental data from Haiti and the Yucatan indicate that there was a very arid climate in the region until about AD 950 [7,9,10]. Such drier conditions would lead to a reduction in flow rates in the rivers that drain into Bluefields Bay resulting in higher salinity, lower turbidity, and less siltation. These conditions would favor the Cardiidae and Veneridae. With an increase in rainfall after AD 950, the near-shore salinity would decrease, and the rivers likely carried heavier sediment and nutrient loads, especially if native peoples were clearing adjacent lands for gardens. These sediments likely contributed to the formation of the second, post-Columbian dune between the sites and the bay. The recently observed progradation of the coastline indicates that this is an ongoing process. Sediments carried by rivers also would have increased turbidity, and introduced fine clays and silts that the Cardiidae and Veneridae cannot tolerate.

In sum, changes in eustatic sea level, changes in rainfall patterns, flow rates in the river drainage, and land clearance for gardens all conspired to make Bluefields Bay a dynamic marine environment. In the same way that animals living in the bay had to adjust to these changes, the human populations that exploited these taxa also had to make adjustments. Although our level of resolution is on the order of centuries, it is sufficient to reveal significant changes over a relatively short period of time.

4. Bioturbation

A final observation concerns modern invertebrate activity. Land crabs (esp. *Gecarcinus* sp.) have caused substantial disturbance to those parts of the Meillacan site that are closest to the swamp. During excavations in this area we encountered six soft round objects, about 5 cm in diameter, at a depth of 48 cm below ground surface. They have since turned up in other parts of the site. On close inspection these turned out to be balls of cow manure. The live insect larva inside one of the balls attests to their recent origin. Previously, Keegan observed land crabs on Grand Turk pulling manure into their holes. We believe that the manure balls in the Meillacan site also are the product of crab activities. What is surprising is that there was no evidence for a crab burrow(s) anywhere near them. Thus, they were our only evidence for recent disturbances. We mention this because the balls have been found in sites on two different islands on which crabs, cows, and horses share the same habitat. It is thus likely that this form of bioturbation occurs in other tropical settings as well.⁶

5. Conclusions

The two sites at Paradise Park provide clear evidence for human-environmental interactions. When the Ostionan peoples arrived in Bluefields Bay they pursued a variety of procurement strategies one of which included targeting Strombidae. Their capture of the strombids reduced their population numbers and the physical characteristics of the bay limited the recruitment of replacements. The result was overfishing to the point that strombids, and especially adult *S. gigas*, were not abundant in Bluefields Bay by Meillacan times. *Cittarium pica* also was extirpated from the small rocky intertidal habitat on Bluff Point.

There also was a clear change in infaunal mollusk use from Ostionan to Meillacan times. The change reflects a shift from more easily procured shallow burrowing Cardiidae and Veneridae to the more deeply burrowing Lucinidae. This shift in mollusk use was in part due to changes in the near-shore coastal environment as mangrove and muddy substrate habitats replaced seagrass habitats. Although the collection of Lucinidae may have required more effort, the additional cost may have been at least partially offset by the corresponding increase in available biomass. As Jackson notes, lower diversity is correlated with greater number and size [12,13]. The need for additional molluscan biomass may have resulted from the declining availability of sea turtles, large fish, and *S. gigas* [5].

Invertebrate remains in West Indian sites are viewed primarily as food or tool sources. Yet in most cases mollusks, even the large *S. gigas*, probably made a relatively minor contribution to the diet. For example, stable isotope analysis has indicated that less than 10% of the prehistoric Bahamian diet was obtained from mollusks [16]. Although mollusks are conspicuous because their shells are readily preserved, it may be more appropriate to view most their use as a garnish or flavoring in stews.

Our data suggest the need to expand the ways in which we interpret mollusks from West Indian sites. By moving away from a strict dietary approach, we can gain a clearer perspective on the local marine environment and its changes through time. The invertebrates from these two adjacent sites at Paradise Park, Jamaica, indicate that Bluefields Bay was transformed by natural and cultural processes from a free-circulating, high-salinity seagrass habitat to a more stagnant, low-salinity seagrass environment with a developed coastal mangrove habitat between the 9th and 15th centuries AD. The evolution of Bluefields Bay continues to the present.

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⁶ We jokingly call this process pooturbation.

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